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FOR

PROJECTION APPARATUS WITH AXIS PARALLEL MICRO MIRRORS AND LIGHT SOURCES

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BACKGROUND

Historically, projection engines of projection systems have been designed employing high intensity discharge lamps. These prior art projection engines/systems suffer from a number of disadvantages. For examples, the lamps typically have relatively short lives, and reduced brightness after an initial period of usage. Further, there is an appreciable period of waiting for the lamp to warm up, when a projection engine/system is first turned on. During that period, either no image is available or the available images are of poor quality. Additionally, active cooling arrangements are typically required to dissipate the heat created during operation.

Resultantly, there has been a lot of interest in developing and manufacturing in a mass scale projection engines and projection systems employing solid state light sources. Such engines/systems typically either do not have or have the aforementioned disadvantages in a lesser degree. Examples of solid state light sources include but are not limited to light emitting diodes (LED), laser diodes and so forth.

Figure 1 illustrates a plane view of a typical solid state light source and micro mirror light valve based projection system architecture. The plane view may be a top view or a side view of the projection system. As illustrated, solid state light source based projection system **100** includes a number of primary color solid state light sources, such as LED **102-106** sourcing red (R), green (G) and blue (B) lights respectively. LED **102-106** are arranged in an orthogonal manner, respectively disposed on 3 sides of prism or dichroic combiner **108**. Prism or dichroic combiner

108 is employed to combine the lights emitted by LED **102-106**. Further, light integrator **110** is placed in the light path to enhance the combined light. Mirror **112** is employed to reflect the enhanced light onto micro mirror device **114**.

Micro mirror device **114** includes a number of micro-mirrors that may be individually tilted to an "on" or an "off" position to selectively reflect the enhanced light reflected from mirror **112** towards projection lens **116** ("on") or away from projection lens **116** ("off"). Resultantly, with each micro mirror corresponding to a pixel, and by selectively controlling their positions, an image or a series of images, including a series of images forming a motion picture, may be projected.

While the architecture of **Fig. 1** works well, it is nevertheless desirable to further improve on reducing the cost and/or increasing reliability of the next generation of projection engines and projection systems.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be described by way of the accompanying drawings in which like references denote similar elements, and in which:

Figure 1 illustrates a plane view of a typical prior art solid state light source based projection engine/system;

Figure 2 illustrates a plane view of a projection engine/system in accordance with one embodiment of the present invention;

Figure 3 illustrates a front view of a micro mirror including its tilt axis and on/off positions;

Figures 4a-4b illustrate two diagonal end views of a micro mirror in accordance with one embodiment;

Figure 5 illustrates a perspective view of the micro mirror device and the light sources of **Fig. 2**, including their geometric relationship; and

Figure 6 illustrates an example projection system in accordance with one embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of the present invention include but are not limited to projection engines and projection systems having axis parallel micro mirrors and lights sources.

In the following description, various aspects of embodiments of the present invention will be described. However, it will be apparent to those skilled in the art that other embodiments may be practiced with only some or all of the described aspects. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the embodiments. However, it will be apparent to one skilled in the art that other embodiments may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the description.

Various operations will be described as multiple discrete operations in turn, in a manner that is most helpful in understanding the embodiments, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

Referring first to **Fig. 2** wherein a plane view of a projection engine (which may be a portion of a projection system) **200** in accordance with one embodiment of the present invention is illustrated. Similar to **Fig. 1**, the plane view may be a top view or a side view of projection engine/system **200**. As illustrated, for the embodiment, projection engine/system **200** includes light sources **208**, micro mirror device **214**, and projection lens **216**, optically coupled to each other as shown.

As illustrated in further detail in **Fig. 3** (which is a plane view of micro mirror device **214** in a plane orthogonal to the plane of **Fig. 2**), micro mirror device **214** includes a number of micro mirrors **302**. In particular, each micro mirror **302** has a tilt axis **304** over which the micro mirror may tilt in one or more directions to allow micro mirror **302** to assume at least two positions. In one position, micro mirror **302** reflects light towards projection lens **216**. In this position, micro mirror **302** is said to be in the "on" position. In another position, micro mirror **302** reflects light away from projection lens **216**. In this other position, micro mirror **302** is said to be in the "off" position.

Referring to **Fig. 2** again, accordingly, lights selectively emitted from light sources **208** may be selectively reflected by micro mirrors **302** of micro mirror device **214** towards projection lens **216** for use to project an image, or a series of images, including a series of images forming a motion picture.

In various embodiments, each micro mirror **302** may correspond to a pixel of an image.

Still referring to **Fig. 2**, for the embodiment, light sources **202-206** are preferably solid state light sources, such as light emitting diodes (LED), laser diodes or other light emitting elements of the like. Moreover, light sources **202-206** may be primary color light sources. In various embodiments, primary color light sources **208** comprise at least one each of a red (R) color light source **204**, a green (G) color light source **206**, and a blue (B) color light source **208**. Alternate embodiments may be practiced with other primary colors.

As illustrated in further detail in **Fig. 4a-4b** (which are diagonal end views of a micro mirror **302**), typically, the amount of tilt between the "on" and the "off"positions is about 14 degrees. For the embodiment illustrated in **Fig. 4a-4b**, micro mirror **302**

tilts in two directions. However, as described earlier, in alternate embodiments, micro mirror **302** may tilt in one direction only.

Again referring back to **Fig. 2**, light sources **208**, comprising of constituting light sources **202-206**, are disposed along axis **212**, referred to as light source axis.

As illustrated in further detail in **Fig. 5** (which is a perspective view of micro mirror device **214** and light sources **208**), light source axis **212** on which light sources **202-206** are disposed, is advantageously parallel to tilt axes **304a-304g**.

As illustrated, with the aid of a coordinate system which x and z axes coincide with the "bottom" and "right" edges **502** and **504** respectively, and the origin coincides with the "lower right" corner **510** of micro mirror device **214**, tilt axis **304d** of the diagonal micro mirrors may be considered as being coincident with the line including points (a, 0, 0) and (0, 0 c), which is disposed on the plane where y = 0. Geometrically speaking, the line may be characterized by the equation z = - (c/a) * x + c with y = 0.

Employing the same coordinate system, light source axis **212** may be considered as being coincident with the line including points (-a, b, 0) and (0, b, 0), which is disposed on the plane where y = b. Geometrically speaking, the line may be characterized by the equation z = - (c/a) * x with y = b.

Accordingly, tilt axis **304d** and light source axis **212** are parallel to each other. Similarly, since tilt axes **304a-304c** and **304e-304g** are parallel to tilt axis **304d**, these tilt axes **304a-304c** and **304e-304g** and light source axis **212** are also parallel to each other.

In view of the geometric manner each micro mirror **302** tilts to reflect lights towards or away from lens **216**, "parallel" light source axis **212** advantageously provides the "largest" or "most flexible" geometric range, relative to other axial arrangements, to accommodate multiple ones of lights sources **202-206**.

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Further, in various embodiments, light sources **208** are designed to illuminate with illumination cone angles that are expanded in the direction parallel to tilt axis **304**. The anamorphic illumination enables brightness to be enhanced without loss of contrast.

Therefore, when so disposed, multiple light sources **202-206**, especially solid state embodiments, may be employed to form light sources **208** providing the desired anamorphic illumination. In turn, projection engine/system **200** may be formed without the need to employ a prism/dichroic combiner, nor a light integrator. Resultantly, a projection engine/system **200** so formed, is likely to be more compact, possibly more cost effective, as well as possibly brighter without loss of contrast.

Still referring to **Fig. 5**, in addition to being parallel to each other, such that the "on" state is directed through the projection lens, for the embodiment, light source axis **212** is "offset" to one side of micro mirror device **214**. In other words, light sources **204-208** project onto micro mirrors **302** of micro mirror device **214** in an angular or non-orthgonal manner. While for ease of understanding, only one offset position (to the – x direction (without any offset in the +/- z direction), in term of the coordinate system of **Fig. 5**) has been illustrated, alternate embodiments may be practiced with light source axis **212** offset in other directions. These other directions may include but are not limited to offset in the – x direction with offset in the +/- z direction, or to the + x direction with or without offset in the +/- z direction.

Referring again to **Fig. 3** and **5**, while for ease of understanding, only 16 micro mirrors are shown for each micro mirror device **214**, in practice, micro mirror device **214** typically includes many more micro mirrors. For examples, various embodiments of micro mirror device **214** may include as many as 1,024 micro mirrors.

Further, while for ease of understanding, only the diagonal version of tilt axis **304** has been illustrated and described, in practice, micro mirrors **302** may tilt over a horizontal axis or a vertical axis. In the former case, the horizontal axis runs horizontally along a center portion of micro mirror **302** (dividing micro mirror **302** in two substantially equal portions, an "upper" portion and a "lower" portion). Correspondingly, light source axis **212** would be a parallel "horizontal" axis.

In the latter case, the vertical axis runs vertically along a center portion of micro mirror **302** (dividing micro mirror **302** in two substantially equal portions, a "left" portion and a "right" portion). Correspondingly, light source axis **212** would be a parallel "vertical" axis.

In other words, tilt axis **304** may be any one of a number of types of tilt axes. Embodiments of projection engine/system **200** will be formed with light sources **202-206** forming light sources **208** correspondingly disposed on a substantially parallel axis, providing sufficient amount of space and flexibility for the accommodation of the multiple desired ones of light sources **202-206**.

Referring now to **Fig. 1** and **5**, while for ease of understanding, three light sources **204-206** are illustrated, alternate embodiments may be practiced with more or less light sources being disposed along the parallel light source axis **212**. Further, while light sources **204-206** have been described as single primary color solid state light sources, such as R, G and B LED/laser diodes, alternate embodiments may be practiced with multiple color solid state light sources, and/or light sources of other primary colors.

Referring now to **Figure 6**, a block diagram illustrating a projection system in accordance with an embodiment of the present invention is shown. As illustrated, projection system **600** includes micro mirror device **214**, light sources **208** and projection lens **216**, optically coupled to each other as earlier described.

Further, projection system **600** includes processor **602** and digital input interface **604** coupled to each other and the earlier enumerated elements as shown.

Digital input interface **604** facilitates provision of data of an image to be projected to processor **602** in digital form. As described earlier, the image may be an image of a series of images, in particular, a series of images forming a motion picture. Processor **602** in turn controls light sources **208** and micro mirrors **302** of micro mirror device **214** accordingly, based on the data provided, to facilitate projection of the image through projection lens **216**.

Processor **602** and digital I/O interface **604** represent broad corresponding ranges of the elements. In various embodiments, processor **602** may be a general purpose microprocessor, while in other embodiments, it may be a special purpose application specific integrated circuit (ASIC). Similarly, in various embodiments, digital I/O interface **604** may e.g. be a DVI compliant (or compatible) interface (i.e. compliant or compliant to DVI 1.0 Specification published by DDWG. [DVI = Digital Video Interface, and DDWG – Digital Display Working Group.]

Thus, it can be seen from the above description, a projection engine and a projection system having axis parallel micro mirrors and light sources have been described. While the present invention has been described in terms of the foregoing embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. Other embodiments may be practiced with modification and alteration within the spirit and scope of the appended claims. Accordingly, the description is to be regarded as illustrative instead of restrictive.